INDOOR AIR QUALITY ASSESSMENT

Greenfield Public Library
402 Main Street
Greenfield, Massachusetts

Prepared by:
Massachusetts Department of Public Health
Bureau of Environmental Health
Indoor Air Quality Program

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Background

Building:	Greenfield Public Library (GPL)
Address:	402 Main Street Greenfield, MA
Assessment Requested by:	George VanDelinder, Central Maintenance Director, Town of Greenfield
Reason for Request:	General indoor air quality (IAQ) and water damage/mold growth concerns
Date of Assessment:	October 18, 2019
Massachusetts Department of Public Health/Bureau of Environmental Health (MDPH/BEH) Staff Conducting Assessment:	Michael Feeney, Director, IAQ Program
Building Description:	The library contains two wings in a split-level configuration. “The library resides in the historic Leavitt-Hovey House, a wooden structure built in 1797, with east and west wings added in 1817. In 1907, the town of Greenfield took the house and property by eminent domain to establish a public library. A 4,000 square foot masonry addition designed to hold the adult book stacks was added to the north of the original building in 1908, and the Greenfield Public Library opened on January 11, 1909. In 1952, a 500 square foot bookmobile garage was added to the east wing” (GPL, 2016). The GPL was renovated in 1998 (MJA & KL., 1998). The second floor of the 1797 wing is used for administrative offices. The ground floor of the 1907 wing contains a conference room, an office and restrooms. The basement of the 1797 wing is used for storage of books and contains a mechanical room and the custodial office.
Windows:	Openable

Previous Recommendations

An assessment of this building was conducted in 2001, with a report finalized in 2002 including recommendations to improve IAQ based on assessment findings. In the 2002 report, the following recommendations were made (with note indicating action taken):

1. Consider replacing carpeting in the basement conference room with tile or other non-porous surface. *Note: original carpeting replaced with carpet tile.*
2. Extend condensation drains to empty at ground level. *Note: no extensions appear to have been installed.*
3. Continue to remove clinging ivy from the exterior walls of the GPL. *Note: clinging plants have regrown to cover rear portions of GPL.*
4. Examine the feasibility of providing mechanical exhaust ventilation for the basement book stacks and the second floor offices. For the second floor offices with univents, examine the feasibility of converting the existing airshafts of the original ventilation system into mechanical systems. Contact an HVAC engineering firm to determine if existing vents, ductwork, etc. can be retrofitted for mechanical ventilation. *Note: no remedial efforts regarding exhaust ventilation were taken.*
5. Install a gutter/downspout system to properly drain rainwater away from the foundation. *Note: no gutter system was installed.*

Methods

Please refer to the IAQ Manual for methods, sampling procedures, and interpretation of results (MDPH, 2015).

IAQ Testing Results

The following is a summary of indoor air testing results (Table 1).

- ***Carbon dioxide levels*** were below the MDPH guideline of 800 parts per million (ppm) in all areas assessed, indicating adequate fresh air in the space at the time of this assessment.
- ***Temperature*** was within the recommended range of 70°F to 78°F in all areas assessed.
- ***Relative humidity*** was within or close to the lower end of the recommended range of 40% to 60% in areas assessed.
- ***Carbon monoxide*** levels were non-detectable (ND) in all areas assessed.
- ***Fine particulate matter (PM2.5)*** concentrations measured were below the National Ambient Air Quality Standard (NAAQS) level of 35 μg/m^3 in all areas assessed.

The assessment results indicate that the ventilation system is providing adequate fresh air for the occupancy in the building. Note that many areas had low occupancy, which can reduce the creation of carbon dioxide. To maximize air exchange, the BEH recommends that mechanical ventilation systems operate continuously during periods of occupancy. Without the system operating as designed, normally occurring pollutants cannot be diluted or removed, allowing them to build up and lead to IAQ/comfort complaints.

Ventilation

A heating, ventilating, and air conditioning (HVAC) system has several functions. First it provides heating and, if equipped, cooling. Second, it is a source of fresh air. Finally, an HVAC system will dilute and remove normally occurring indoor environmental pollutants by not only introducing fresh air, but by filtering the airstream and ejecting stale air to the outdoors via exhaust ventilation. Even if an HVAC system is operating as designed, point sources of respiratory irritation may exist and cause symptoms in sensitive individuals.

Fresh air is supplied by a unit ventilator (univent) system (Figure 1). Univents draw air from outdoors through a fresh air intake located on the exterior walls of the building and return air through an air intake located at the base of each unit. Fresh and return air are mixed, filtered, heated and provided to rooms through an air diffuser located in the top of the unit. Univents were functioning in the majority of areas examined.

Exhaust ventilation is provided by ceiling-mounted exhaust vents in the first floor library areas. The basement conference room has a wall-mounted exhaust vent, which is connected to a large fan installed on the rear exterior wall. In all areas examined, exhaust vents were deactivated. Without a functional exhaust system, normally occurring environmental pollutants can build-up and lead to indoor air quality complaints.

The administrative offices on the second floor do not have mechanical exhaust ventilation. The roof of the 1797 wing has two chimney-like structures, which appear to be exhaust ventilation airshafts. A large grill in the staff office appears to be connected to the western brick ventilation shaft by ductwork in the attic. A second large grill located at the top of the stairwell from the first floor may be connected to the eastern brick ventilation shaft. The sound of vehicle traffic was noted emanating from this grill, indicating the airshaft is likely open to the outdoors. These vents are not mechanical, but use rising, heated air to draw environmental pollutants from the building. While this system can work well during the heating season to provide exhaust ventilation, the system does not work during the air conditioning season. These vents may also serve as a moisture source during summer weather. Additionally, a number of areas in the basement do not have a mechanical fresh air supply system (Table 1).

It is also important to note that the HVAC system is over 20 years old. Efficient function of equipment of this age is difficult to maintain, since compatible replacement parts are often unavailable. According to the American Society of Heating, Refrigeration and Air-Conditioning Engineering (ASHRAE), the service life[1] for the various components of the HVAC system is between 20 to 30 years, assuming routine maintenance of the equipment (ASHRAE, 1991). Despite attempts to maintain the equipment, the optimal operational lifespan of this equipment has been exceeded.

To maximize air exchange, the IAQ program recommends that both supply and exhaust ventilation operate continuously during periods of building occupancy. In order to have proper ventilation with a mechanical supply and exhaust system, the systems must be balanced to provide an adequate amount of fresh air to the interior of a room while removing stale air from the room. The date of the last servicing and balancing was not available at the time of the assessment. It is recommended that existing ventilation systems be re-balanced every five years to ensure adequate air systems function (SMACNA, 1994).

Microbial/Moisture Concerns

Room B101 had extensive water damage along its western wall (Picture 1). It also appears that repairs were attempted in the past in the form of gypsum wallboard (GW) patches used to fill holes in the base of the plaster wall (Picture 2), as indicated by the presence of paper inside the wall. The use of GW as a patch is inappropriate since the paper backing can become mold-colonized if chronically wet. The likely source of moisture causing this damage is pooling water against the foundation. Cement slabs were placed against the foundation to form a walkway and provide some amount of water drainage from the building. Chronic exposure to

[1] The service life is the time during which a particular system or component of …[an HVAC]… system remains in its original service application and then is replaced. Replacement may occur for any reason, including, but not limited to, failure, general obsolescence, reduced reliability, excessive maintenance cost, and changed system requirements due to such influences as building characteristics or energy prices (ASHRAE, 1991).

rainwater has resulted in the cement slabs subsiding and losing sealant. In addition, the subsidence has created a trench next to the building which will further prevent drainage (Picture 3). Water likely accumulates in the trench, which then penetrates through the exterior wall to damage interior wall plaster and serve as a moisture source for water vapor to accumulate beneath carpet tiles.

Water-damaged ceiling tiles were observed in a number of areas. Some of the observed stained tiles were from roof leaks that have reportedly been repaired. The roof of the building was also examined. The roof membrane had become loose, resulting in pooling water (Picture 4). Debris is also present from tree branches that overhang the roof. Debris holds moisture on the roof, which can damage the membrane and can be attractive to pests.

During the summer of 2018, the Boston area experienced an unprecedented period of extended hot, humid weather. According to the Washington Post, "[d]ata…show[s]…cities in the Northeast have witnessed such humidity levels for record-challenging duration...[i]ncluding Albany, Boston, Burlington Portland and Providence" during the summer of 2018 (WP, 2018). "Boston and nearby locations… [saw]…historic numbers of those warm nights with low temperatures at or above 70 degrees…Providence and Blue Hill Observatory have already broken their annual records" (WP, 2018).

If a building does not have adequate exhaust ventilation and air chilling capacity to remove/reduce relative humidity from outside air, then hot, moist air introduced into a building can linger to increase occupant discomfort as well as possibly moisten materials that may lead to mold growth.

As noted previously, the building is configured in a manner where significant hot, moist air can readily pass into interior of the building. Other sources of hot, humid air impacting the main offices include spaces around the basement door, as well as outdoor exterior doors. Note that both liquid water and water vapor can create conditions conducive to fungal colonization of vulnerable materials. Leaks through the building envelope (e.g., roof, exterior wall components, and foundation) or plumbing issues are obvious water sources. High relative humidity combined with hot weather can also cause damage. Under certain conditions, condensation[2] can accumulate

[2] Condensation is the collection of moisture on a surface with a temperature below the dew point. The dew point is a temperature determined by air temperature and relative humidity. For example, at a temperature of 73°F and relative humidity of 57 percent indoors, the dew point for water to collect on a surface is approximately 57°F.

and moisten materials. If these materials are porous, carbon-containing items (e.g., gypsum wallboard, carpeting, cloth, paper, and cardboard), mold can grow.

The key to managing condensation in hot, humid weather indoors is understanding dew point. When warm, moist air passes over a cooler surface, condensation can form. Condensation is the collection of moisture on a surface at or below the dew point. The dew point is the temperature that air must reach for saturation to occur. If a building material/component has a temperature *below the dew point*, condensation will accumulate on that material. Over time, condensation can collect and form water droplets.

According to American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), if relative humidity exceeds 70%, mold growth may occur due to wetting of building materials (ASHRAE, 1989). It is recommended that porous material be dried with fans and heating within *24 to 48 hours of becoming wet* (US EPA, 2008, ACGIH, 1989). If porous materials are not dried within this time frame, mold growth may occur. Water-damaged porous materials cannot be adequately cleaned to remove mold growth.

Building Materials Prone to Condensation

A method to locate areas in a building prone to condensation would be to measure air and building material temperatures. If a wide temperature range exists between measurements, the building materials at the colder end of the range may be prone to becoming moistened with condensation in hot, humid weather.

Using a laser thermometer, the surface temperature of the following locations were measured: interior walls, window frames, GW in close proximity to the floor, and floor temperature approximately five feet (5′) from exterior walls. Air temperature and relative humidity were also measured. Several conditions were noted (Table 2):

- Measurement of wall temperature was done during a clear day with solar heating. Wall temperatures measured in a range from 59 to 63°F, while the indoor temperature was in a range of 70 to 72°F. The difference in temperature indicates that the walls are not insulated or energy efficient and can serve as thermal bridges[3]. Where a thermal bridge

[3] A thermal bridge is an object (usually metallic) in a wall space through which heat is transferred at a greater rate than materials surrounding it. During the heating season, the window comes in contact with heated air from the interior and chilled air from the outdoors, resulting in condensation formation if the window frame temperatures are below the dew point.

exists, condensation is likely to form on the warm side of the cold object, which can moisten materials, such as plaster.

- Floor temperatures were also measured in a range from 59 to 63°F, while the indoor temperature was in a range of 70 to 72°F. The floor is likely not insulated and can serve as a thermal bridge, leading to potential condensation on the floor, which can moisten carpeting and items placed on the floor.

In each of these instances, the lower temperature of the floors and walls combined with the presence of thermal bridges in addition to possible water penetration through the cement floor from poorly draining rainwater (rooms B101/B103) make these materials vulnerable to moistening and mold growth under the weather conditions experienced in Massachusetts over the summer of 2018.

Exterior Conditions Impacting the Building

An oak tree exists near the southeast corner of the GPL property, which overhangs the roof (Picture 5). This tree poses a number of hazards to the GPL as well as a possible danger to free egress for the Greenfield Fire Department (GFD) from its firehouse driveway:

- As reported by Greenfield public officials, the roots of the oak tree are entering sewer pipes for the GPL, resulting in blockage.
- Leaves and acorns accumulate around the flat roof drain, which creates a dam that inhibits rainwater drainage from the roof. This condition can also lead to ice accumulation blocking this drain, which can lead to water running off the roof to moisten exterior walls.
- The oak tree prevents sunlight from drying the eastern wall of the GPL.
- The oak tree is a possible danger to the GPL due to its distance from its exterior walls. The recommended safe distance from which an oak tree should be planted is recommended to be approximately 98 feet (33 yards) from the exterior of a building (BI, 2015). Soil subsidence may also be caused by oak tree roots, which can undermine the structure of a building to cause wall and floor cracking as well as other related damage. To prevent subsidence, a 98 feet distance is recommended (Williams, A. 2006). Within this distance, severe weather may

result in the tree falling onto the GPL or having the tree roots damage the sewer service. The oak tree is well within 98 feet from the building.

- Also of note is resistance of the oak tree to uprooting during high wind events. In general a tree root system will spread out in all directions from its trunk. As noted previously, an oak tree root can extend in a 196 foot diameter from its trunk. Any structure disrupting the root structure would then to make the tree unstable if subjected to high winds from a certain direction. The east side of the tree has its root system disrupted by a sidewalk and the driveway of the GFD (Picture 6). A strong westerly wind would make the oak tree prone to falling eastward to block the GFD driveway. If the oak tree is subjected to strong southeasterly winds, which are rare but possible, it is feasible that the tree can uproot to fall on the GPL.

The Federal Emergency Management Agency (FEMA) provides a number of recommendations in order to prepare for severe thunderstorms. Of note FEMA recommends "Cut down or trim trees that may be in danger of falling on your [building]" (FEMA, 2018). Given the proximity to the GPL, the damage done to sewer lines and its location near the GFD driveway, removal of the oak tree should be strongly considered.

Conclusions/Recommendations

Based on observations at the time of assessment, the following is recommended:

1. Consider implementing recommendations in the 2002 report that have not already implemented. A copy of the 2002 report is attached as Appendix A.
2. Remove GW used to repair the basement wall in B103. Repair with an appropriate material (e.g., cement board) that is not susceptible to mold growth.
3. To prevent future water damage from rain/groundwater in basement rooms a number of options to improve drainage from the west-facing wall of the 1907 building can be considered:
    - Install a French drain at the base of the wall;

- Install a water-impermeable apron that resists settling to drain water away from the wall like the tarmac apron installed on the westernmost wall of the building (Picture 7);
- Install a gutter/downspout system to reduce rainwater impact on the cement slabs. Once installed, reset the cement slabs in a manner to prevent settling.

4. It is highly recommended to remove the oak tree from the southwest corner of the building to improve roof drainage and prevent potentially catastrophic damage in severe wind conditions/heavy rain.
5. Given the age of the HVAC system, consideration should be given to having a ventilation engineer examine the HVAC system for upgrade or replacement.
6. In order to prevent mold growth/water damage to building materials in basement areas during extended hot, humid weather (e.g., heatwave). The following actions are recommended:
    - Operate the fresh air supply and exhaust system in the basement levels *continuously* when outdoor relative humidity is greater the 70%.
    - Consider raising the temperature set point for the HVAC system in the basement during periods of hot weather when the building is mostly empty of occupants to limit condensation.
    - Use dehumidifiers in the basement areas to supplement humidity reduction during periods of extended heat with high relative humidity (>48 hours):
        - Dehumidifiers need to be properly drained of water and properly cleaned and maintained.
        - Dehumidifiers only need to be used during periods of high outdoor relative humidity (>70%) during a heat wave.
7. Refer to resource manual and other related IAQ documents located on the MDPH's website for further building-wide evaluations and advice on maintaining public buildings. These documents are available at: http://mass.gov/dph/iaq.

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Picture 1

Room B101 had extensive water damage along its western wall

Picture 2

GW inside plaster wall

Picture 3

Subsiding and ajar cement slabs at base of west wall
(Note missing sealant in slab/wall junction)

Picture 4

Pooling water on roof

Picture 5

Oak tree overhanging building

Picture 6

The east side of the tree has its root system disrupted by a sidewalk and the driveway of the Greenfield Fire Station

Picture 7

Tarmac apron at base of the westernmost wall of the GPL